JOURNAL OF
AGRICULTURAL AND
FOOD CHEMISTRY

Characterization of Char from the Pyrolysis of Tobacco

RAMESH K. SHARMA, JAN B. WOOTEN, VICKI L. BALIGA,
PAMELA A. MARTOGLIO-SMITH,† AND MOHAMMAD R. HAJALIGOL*

Research Center, Philip Morris U.S.A., P.O. Box 26583, Richmond, Virginia 23261-6583

Pyrolysis of tobacco was studied in oxidative and nonoxidative (inert) environments at atmospheric pressure and temperatures ranging from 150 to 750 °C. The objective was to study the effect of pyrolysis conditions on the characteristics of the solid residue, i.e., char. The char was characterized using cross-polarization ^{13}C nuclear magnetic resonance (CPMAS NMR), Fourier transform infrared (FTIR) spectroscopy, scanning electron microscopy (SEM), the Brunauer–Emmett–Teller (BET) surface area, and the elemental composition. The char yield from pyrolysis (i.e., nonoxidative) decreased sharply with an increase in temperature to ca. 22% (dry, ash-free basis) at high temperatures. In oxidative pyrolysis, i.e., in 5% oxygen, the char was completely oxidized above 600 °C. The gaseous product from pyrolysis at high temperatures contained a significant concentration of hydrogen. The surface area of the char was low, with a maximum of 8 m^2/g at 400 °C. SEM analysis indicated that pyrolysis of the tobacco led to a gradual accumulation of inorganic crystals on the exposed surfaces, and some constituents also melted, resulting in the formation of vesicles by evolving gas. NMR analysis showed significant changes in pectin and sugar constituents of the tobacco and breaking of glycosidic bonds of cellulose at 300–500 °C before the char became predominantly aromatic at high temperatures. FTIR results showed a continuous decrease in the intensity of the OH stretch with temperature and the aromatic character to be at maximum at 550–650 °C. The H/C ratio of the char decreased continuously with temperature, while the O/C ratio became constant above 300 °C due to the presence of oxides and carbonates in the char. The results are consistent with the analysis of the evolved gases.

KEYWORDS: Tobacco; char; characterization; pyrolysis

INTRODUCTION

Tobacco has been a widely used agricultural product at least since American colonial times. Currently, high-speed machines fabricate cigarettes by inserting a blend of tobaccos into a paper rod and attaching a filter tip. A cigarette is typically lit by a smoker with a match or other type of lighter and undergoes self-sustaining combustion. Many thousands of chemical substances are generated by combustion and pyrolysis reactions during the formation of cigarette smoke. The peak temperatures in the combustion region of the cigarette coal during a puff can reach 800–900 °C (*1*). Such high temperatures can lead to the formation of polycyclic aromatic hydrocarbons (PAHs). PAHs are ubiquitous products that form during the combustion of many forms of biomass. They can also be found, for example, in charred foods. A growing body of evidence suggests that PAHs arise from the high-temperature pyrolysis of the solid char that is formed at lower heating temperatures (*2–6*). Thus, an understanding of the chemistry of the char may lead to a better understanding of the mechanism of the formation of PAHs.

The pyrolysis of tobacco has much in common with the pyrolysis of other forms of biomass. Pyrolysis of biomass is complex and leads to the formation of many volatile and semivolatile products and a solid residue, i.e., char (*7–11*). The relative distribution of the products is usually dependent on the pyrolysis conditions as well as on the type of biomass. Much of the literature on pyrolysis of biomass is focused on the analysis of the volatile components and the pyrolysis kinetics (*12–15*). Under severe pyrolysis conditions, it is the volatile products that are believed to undergo secondary reactions, resulting in the formation of PAHs (*6, 16, 17*). The extent of such reactions in the product char is not known but could be important under smoldering conditions (*4, 5, 18–20*). The extent of secondary reactions may be dependent on the characteristics of the char.

There is a limited amount of information on the characterization of chars from the pyrolysis of different biomasses. Sekiguchi and Shafizadeh (*19*) and Mok et al. (*21*) found that chars from cellulose, formed at temperatures below 400 °C, had higher concentrations of aliphatic carbons and were more reactive compared to chars formed at higher temperatures. Boon et al. (*2*) also studied cellulose pyrolysis and suggested that the

* To whom correspondence should be addressed.
† Present address: 3641 Braddock Dr., Lafayette, IN 47909.

10.1021/jf0107398 CCC: $22.00
Published on Web 01/18/2002

PM3001115338